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# VARIETAL RESISTANCE AND SUSCEPTIBILITY OF OATS TO CROWN RUST

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Crown rust (*Puccinia coronata* Corda) is a common and widespread disease of oats in the cooler and more humid western districts of England and Wales. It is most prevalent in Wales and south-west England, where heavy attacks occur from time to time when suitable conditions prevail for the early development and rapid spread of the disease. Although little is known about the relative amount of damage caused by the fungus in its attacks at different stages of growth of the crop, observations on numerous varieties have shown that attacks in June and early July can cause serious loss in yield and quality. Normally the disease develops later when crops are beginning to mature and ripen off, and little damage is done.

The uredospores spread the disease within the crop and from one crop to another during the spring and summer. The rust may overwinter either on its alternate host, the buckthorn (*Rhamnus catharticus* L.), or on autumn-sown crops of oats and volunteer plants. In Wales, the latter appear to be the main sources of infection, since the winters are usually not too severe to permit the survival of the uredial stage of the organism from one crop season to another, and the alternate host is confined to a few localities. Nevertheless, the presence of *Rhamnus* in other parts of the country presents a perennial source of infection and is important for the part it plays in the development of new physiological races.

At the moment, there is no effective practical means of controlling crown rust other than by the cultivation of resistant varieties. The importance of resistant varieties in the prevention of losses caused by crown rust has long been emphasized in the United States of America and Canada, and their utilization is a well-recognized method of control.

As a prerequisite to a programme of breeding resistant varieties suitable for general use in this country, it was necessary to study the reactions of individual varieties to the specialized form or forms in which the rust exists here. Investigators in other countries have shown that crown rust of oats comprises many specialized races, each characterized by having different parasitic capabilities on the same varieties of oats.

As far as I am aware, very little work has yet been done either on physiologic specialization or on the reaction of the more widely-grown varieties to the races which exist in this country. Brown (1937) reported the occurrence of three races (6, 22 and 44) and observed their pathogenicity on three fairly widely used varieties, namely, Abundance, Grey Winter and Victory. This paper presents some further information on varietal reactions to eight physiologic races isolated by me during the course of breeding investigations.

Collections of crown rust obtained from several different centres in Wales and south-west England were used to effect the preliminary screening of resistant varieties. In the first series of tests, composite uredospore cultures were used ; later, single-spore cultures were established from the original collections. By means of tests on the standard series of thirteen oat varieties, used by Murphy (1935) for differentiating physiologic races, eight distinctive forms, each



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exhibiting different reactions to the differentials, were isolated from the collections.* In all subsequent tests these were used to observe individual varietal reactions.

### INOCULATION TECHNIQUES

All the tests reported in this paper were carried out in a greenhouse artificially heated during the winter period; the daily temperature ranged from 55° to 65° F. in the autumn, winter and spring. Owing to the difficulties of keeping the greenhouse cool in summer and obtaining sufficient light in the winter, the period of actual testing of varietal reactions was confined to the months of March, April, May, September and October.

Except for slight modifications, the methods employed for the establishment and maintenance of stock cultures were those described by Murphy (1935). The collections were maintained on the variety S.172, which is very susceptible to crown rust even at relatively high temperatures. Reserve stocks were stored in a refrigerator at a temperature of 2° C. Before being placed in the refrigerator, the spore-bearing leaves were first dried over calcium chloride in desiccators. Under these conditions spores maintained their viability for at least 6 months, and, in a number of instances, viable inoculum was obtained after storage for over 12 months.

### SINGLE SPORE INOCULATIONS

When pure cultures were established from single uredospores, the technique of Newton and Johnson (1932) was used. The spores were scattered sparsely over a sterile slide, observed through the lower power of the microscope, picked up separately on the point of a fine needle, and then transferred to the leaf surfaces. It was found necessary to make a number of single-spore inoculations from each collection, since even under optimum conditions less than 20 per cent of the spores inoculated caused infections. No evidence was obtained that more than one race was present in any one collection, although two new races ($PC–AV_7$ and $PC–AV_8$) appeared in the Station's field nursery in the summer of 1952 on breeding material which had previously resisted attack by all races.

After inoculation, the plants were incubated in glass cylinders and sprayed periodically with tap water from an atomizer. The tops of the glass cylinders were covered with glass sheets for the first two days of incubation to provide the high humidity conditions required for successful infection. Pustules generally appeared 10–12 days after inoculation during April, May and September, and after 10–15 days in February, March and October, depending upon the weather conditions prevailing at the time of incubation. At the end of the incubation period the plants were covered with spore-proof transparent plastic cases. Oat seedlings used for single-spore inoculations were inoculated in the second-leaf stage.

### MASS INOCULATIONS

To provide sufficient spore material for the various tests, further inoculations were made. Seedlings used to establish pure cultures or for test purposes were

* Since these races have not been characterized previously, they have been temporarily given the symbols $PC–AV_{1-8}$. Dr. H. C. Murphy of the United States Department of Agriculture has kindly undertaken to check their identity and to assign new accession numerals to them in accordance with the numerical scheme of nomenclature instituted by the United States and Canadian investigators.

inoculated in the first-leaf stage. In the tests designed to assess varietal reactions, 5–10 seedlings were grown in 5-inch earthenware pots, and four pots of each variety were used for inoculation with each culture, so that readings were obtainable from at least 20 seedlings in each case. The leaves were rubbed gently between moistened fingers, and the plants thoroughly wetted by spraying with water ; the inoculum was then applied with a sterilized scalpel—running it over the surfaces of the leaves in such a way as to ensure an abundant and uniform spread of spores. The plants were finally enclosed in the glass cylinders for incubation.

When primary uredospore pustules were fully developed, notes were taken of the type of infection. The types were classified according to the scheme drawn up originally by Stakman and Levine (1922) for the identification of physiologic races of *P. graminis tritici*. In recording the observations, the following five infection classes, designated by the symbols 0 to 4, were recognized. The descriptions of the types, modified slightly to suit the infections obtained in the present investigations, are given below :

| Host Reaction | Symbol and Infection Types |
|---|---|
| Highly resistant ... ... | 0. No uredospore pustules developed ; necrotic or chlorotic flecks usually present. |
| Resistant ... ... ... | 1. Pustules few, minute and isolated ; usually accompanied by pronounced necrosis ; necrotic areas often produced without development of pustules. |
| Moderately resistant ... | 2. Pustules small to medium in size and surrounded by necrotic or markedly chlorotic areas ; necrotic spots rarely without pustules. |
| Moderately susceptible ... | 3. Pustules fairly abundant, medium sized and surrounded by chlorotic areas ; necrotic areas entirely absent. |
| Very susceptible ... ... | 4. Pustules large and abundant, often confluent and showing copious production of uredospores ; no necrosis, and usually no chlorosis. |

A second reading of the infection types was made four days after the first inspection, and occasionally a third reading was taken a few days later. This was necessary because pustules often did not form on fairly resistant hosts until several days after they had appeared on very susceptible ones. Despite the fact that all possible efforts were made to make the tests under conditions as near as practicable to the optimum for development of both host and pathogen, a slight fluctuation within an infection type was observed in some cases, especially on certain varieties. The most common variations were within the 0, 1 and 2 classes. Data on the average infection types produced on a number of varieties and forms of oats inoculated with uredospores from the eight different cultures are given in Table 1.

A total of 40 varieties and selections were inoculated in the seedling stage with each of the eight forms. In the class " susceptible varieties " are grouped 31 varieties representing all the more important ones grown commercially in this country. All of these exhibited pronounced susceptibility to each of the eight cultures.

Of the 9 varieties listed as possessing resistance to one or more of the cultures in the seedling stage, the varieties Bond, Clinton, Eaton, Landhafer, Santa Fé, Shelby, Tama, and Victoria appear to be the most promising for breeding purposes. Landhafer proved resistant to all eight cultures, Victoria and Tama



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resistant to all but one of them, while Bond, Clinton, Eaton and Shelby proved resistant to six of the eight.

TABLE 1

SUMMARY OF INFECTION TYPES PRODUCED ON OAT VARIETIES INOCULATED WITH DIFFERENT CULTURES OF PUCCINIA CORONATA

| Variety Inoculated | Infection Types on Seedling Plants | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Avena sativa* L. | PC–$AV_1$ | PC–$AV_2$ | PC–$AV_3$ | PC–$AV_4$ | PC–$AV_5$ | PC–$AV_6$ | PC–$AV_7$ | PC–$AV_8$ |
| *Susceptible varieties ... | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Clinton ... ... ... | 0 | 0 | 0–1 | 0–1 | 0 | 0 | 4 | 4 |
| Eaton ... ... ... | 0 | 0 | 0–1 | 0 | 0–1 | 0–1 | 4 | 3 |
| Santa Fé... ... ... | 1–2 | 1 | 1 | 0–1 | 3 | 3 | 2 | 1 |
| Shelby ... ... ... | 0 | 0–1 | 0–1 | 0 | 0 | 0–1 | 4 | 4 |
| Tama ... ... ... | 0–1 | 0–1 | 0–1 | 0–1 | 0–1 | 0–1 | 3–4 | 0–1 |
| Victoria ... ... ... | 0–1 | 0–1 | 0–1 | 0–1 | 0–1 | 0–1 | 3–4 | 0–1 |
| †Cc 4146 ... ... ... | 4 | 4 | 4 | 1 | 4 | 4 | 4 | 4 |
| *Avena byzantina* C. (Koch) | | | | | | | | |
| Bond ... ... ... | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 |
| Landhafer ... ... | 0–1 | 0–1 | 0–1 | 0 | 1 | 0–1 | 0–1 | 1–2 |

* Winter oats: Black Winter, Bountiful, Grey Winter, Picton, S.81, S.147, S.172, Unique. Spring oats: Abundance, Black Supreme, Black Tartarian, Blenda, Borris Opus, Ceirch-du-bach, Craig's Afterlea, Eagle, Early Miller, Englebrekt, Golden Rain II, Marvellous, Onward, Orion III, Radnorshire Sprig, Scotch Potato, Star, Sun II, S.84, S.220, Maldwyn (S.221), Milford (S.225), Victory.

† Unidentified hexaploid form believed to have been derived from a natural cross between *A. sativa* L. and *A. ludoviciana*.

On the basis of the results obtained from the preliminary tests, the varieties Bond, Victoria, Tama, and, later, Clinton and Shelby, were used extensively in the breeding programme. One noteworthy feature of these varieties, however, was their extreme susceptibility to mildew. Clinton proved to be one of the most susceptible of all the cultivated varieties tested for resistance to mildew (Jones and Griffiths, 1952).

Up to July 1952, both Bond and Victoria, together with the other varieties and selections bred from these two varieties, proved resistant to all cultures, but in July of the same year all varieties and selections grown in the field nursery and possessing the resistance factors of Bond and Victoria succumbed to attack just before maturity. Collections of uredospores made from the field nursery revealed the existence of the two new races (PC–$AV_7$ and PC–$AV_8$) which hitherto had not been isolated. As shown in Table 1, Bond proved susceptible to both, while Victoria proved susceptible to PC–$AV_7$ but resistant to PC–$AV_8$. Insufficient data are available to decide whether these two new races will become so prevalent as to threaten the effectiveness of the resistance possessed by any new selections of oats derived from either Bond or Victoria. Landhafer was the only variety which proved highly resistant to eight races, and it is thus an important source of resistance for further breeding work. As yet, selections with Landhafer germ plasm have not been developed.

Observations on the reactions of mature plants to six cultures (PC–$AV_{1-6}$) were carried out under glasshouse conditions. The results obtained agreed closely with those obtained for the seedling stage, but in the cases of Landhafer and Santa Fé, and to some extent Victoria and Tama, the expression of resistance appeared to become less effective in controlling the infection as the plant tissues became older and slight sporulation occurred. This was also evident in the field nursery, where the plants were subjected to natural infection.

### BREEDING VARIETIES RESISTANT TO CROWN RUST

In addition to knowing the reaction of individual varieties of oats to the various races of crown rust in this country, and isolating suitable resistant varieties for hybridization with varieties adapted for cultivation in Britain, a knowledge of the mode of inheritance of resistance is also necessary. Of the varieties listed in Table 1 as possessing resistance to most of the cultures isolated at Aberystwyth—namely, Bond and its derivatives, Clinton, Eaton and Shelby ; Victoria and its derivative Tama ; Landhafer and Santa Fé—the mode of inheritance of their resistance to a number of races identified elsewhere has already been established. The resistance of Bond, which approaches immunity, is conditioned by two dominant complementary factors (Hayes *et al*, 1939 ; Litzenberger, 1949), while the hyper-sensitivity type of resistance possessed by Victoria and its derivatives is dependent upon one dominant factor (Litzenberger, 1949). Resistance in Landhafer and Santa Fé is also governed in each case by single dominant factors.

Observed segregation for reaction to the first six cultures of crown rust identified before July 1952, in crosses involving Bond and its derivatives and Victoria derivatives, confirmed the results of the American investigators (Griffiths, unpublished data).

With the appearance of a new physiologic form capable of attacking both Bond and Victoria, the development of varieties possessing resistance to all eight races reported above can only be accomplished by utilizing Landhafer as a parent for hybridization.

It is thus clear that if a really effective control of crown rust of oats is to be achieved by breeding, information on physiologic specialization, distribution of the physiologic races within the region, and varietal reactions to individual races is essential to the breeder. The appearance of new races may necessitate a further search for new sources of resistance.

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# PEST ASSESSMENT WORK IN ENGLAND AND WALES, 1946-51

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In November 1946 the N.A.A.S. Conference of Advisory Entomologists approved a pest assessment scheme submitted by a sub-committee which had been appointed to investigate, and make recommendations on, the introduction of a series of routine surveys on economic pests. The main purpose of the scheme was to record the fluctuations from year to year in insect populations and in damage done to susceptible crops, and to see what correlation existed between them.

During the period 1946–51, survey work followed the lines of the sub-committee's recommendations. A wide range of pests was investigated and valuable experience gained. With the exception of a progress report on Frit fly, Cabbage aphid and the Black Bean aphid (Thomas, 1948), and a summary of six years' results on Cabbage aphid (Empson, 1952), none of this work has been published. This is partly because it is inadvisable to commit the finding from such work to print until four or five years' results are available for comparison, and partly because the results of some of the " reconnaissance surveys " were inconclusive.

Entomological literature of the past fifty years indicates that patterns of thought are changing. During the first twenty-five years there was a glut of taxonomic papers and papers describing the biology and natural history of insects ; latterly, the trend has been towards ecology. Entomologists are now beginning to realize that pests must be studied in relation to their environment if control is to be economically effected. But there is still a great dearth of published information on the methods that can be used for quantitative field studies on insect pests, and an even greater lack of published results from such studies. It has therefore been decided to publish the N.A.A.S. reconnaissance survey results, and this article forms an introduction to a series summarizing the work carried out on some of the pests surveyed quantitatively over the period from 1946 to 1951.

Insufficient research has been done on the biology, habits and behaviour of economic pests for population survey results to be interpreted with confidence. Many important ecological variables are known to affect insect populations in the field, and some " guiding principles " were laid down in 1946 as a basis for site selection. Sites were to be chosen as representative and typical of the possible areas considered to be of interest, with special attention to sites in areas where susceptible crops were common. The number of sites in any N.A.A.S. province was not to vary from year to year, and their locations were to be fixed as closely as possible—for example, they were to be on certain farms, or on fields as near as possible to a certain point on the map, year after year. Care was to be taken that the character of a site (soil type, altitude, etc.) was roughly the same from year to year.

Except in a survey of *Myzus persicae*, no detailed information was requested on site characteristics, though in several cases additional information on other ecological factors was asked for. Sowing date, for instance, was to be noted in the case of oat fields sampled for Frit fly, and only swedes growing on fields

not cropped the previous season with Cruciferae were to be sampled for Swede midge.

Although a survey of leatherjacket infestations has been of interest, the results with pests producing more than one generation a year have generally been disappointing. In the survey of Cabbage aphid on Brussels sprouts, for instance, autumn " peak " infestations were assessed in terms of plants that were " clean ", " slightly ", " moderately ", or " severely " infested with aphids —these ranking terms being carefully defined. While there is not much doubt that the severely infested plants produced little or no saleable yield of Brussels sprouts, it has proved impossible to interpret slight and moderate infestations in terms of loss of yield. Again, it was not possible to interpret estimates of damage by Cabbage Root fly or Mangold fly in terms of loss of crop ; it seems likely in both cases that the host plants possess great powers of recovery and, given the right weather at the right time, can grow right away from severe early attacks.

By the end of 1950 it was clear that the results being obtained from the reconnaissance surveys were of very limited value and were not usually fulfilling the main purpose of the scheme laid down in 1946. The scheme was therefore revised. In the first place it was agreed that each pest should be studied intensively, even though this would inevitably restrict the number surveyed in any year to two or three species. The basic task was clearly to carry out detailed field experiments to determine accurately the relationship between pest numbers, activity, and the yield of host crops. It might then be possible to evolve reliable, rapid survey methods which could be used to provide accurate routine estimates of annual pest damage. But before accurate field experiments could be carried out, it was obvious that sampling methods of known reliability —both for the pests and for the crops—would be required.

The Cabbage aphid was selected as the first pest for intensive study, and by the end of the 1951 season a reliable sampling method, which could be applied independently of individual bias, had been evolved. Field experiments on the accurate assessment of loss of yield caused by naturally-occurring Cabbage aphid populations were started, and the results of the first season's work were most encouraging. The Cabbage aphid plot work was continued in 1952, and is scheduled to last for another two or three seasons ; by this time, sufficient reliable data should be available for the evolution of a new rapid survey scheme. Detailed work on Frit fly was also started in 1952, and results from the first season's experiments are as encouraging as those for Cabbage aphid. Here it has been possible to use the reconnaissance survey results as a basis for the sampling methods used.

There is no easy road to accurate pest and pest damage assessment. Original estimates of the time and effort required have had to be basically revised. Thus, while in 1946 it was thought that five to ten fields per N.A.A.S. province would give reasonable estimates of pest abundance, it is now known that a minimum of twenty random fields per province must be surveyed to obtain damage estimates which will be within 20 per cent of the correct value nine times out of ten.

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# SURVEY OF LEATHERJACKET POPULATIONS IN ENGLAND AND WALES, 1946-51

*Contribution from the Conference of Entomologists, National Agricultural Advisory Service, compiled by M. Cohen, N.A.A.S., Shardlow, Derby*

As mentioned elsewhere in this issue, one of the recommendations about pest assessment made by a sub-committee of the N.A.A.S. Conference of Advisory Entomologists appointed in 1946 to investigate the problem was for a survey of leatherjackets (*Tipula* spp.) in England and Wales. At first, no attempt was made in the survey to estimate populations : it was required only that general observations be made, in June, of ten well-distributed fields after grass—the crop to be specified. This preliminary work indicated that to obtain more precise data a sampling technique was essential, and that the observations would have to be made earlier in the year.

In December 1947 (as a result of trials in the Northern Province) a sampling method was recommended based on the ortho-dichlor-benzene technique of Barnes (*Ann. appl. Biol.*, 1937, **24**, 356–68). Observations were to be made in April, on at least five well-grazed permanent pastures. Ten square-yard plots were to be sampled at random, using St. Ives leatherjacket mixture (25 cc. in 2 gallons of water) soaked into the ground at the rate of 1 gallon per square yard. The leatherjackets visible on the surface within five minutes of treatment were to be counted. The instructions were qualified by reference to the preparation of the sample site, and the fact that different types of soils under varying weather conditions might need different quantities of fluid to ensure adequate soaking of the roots. Sites thought to be favoured by Crane flies were to be chosen, and while a minimum of five fields was suggested for each province, it was hoped that more would be sampled. For the 1951 sampling the technique was revised, and 20 one foot-square random samples were each treated with 1 pint of the standard leatherjacket fluid. Sample areas were sharply delimited by pressing a metal frame into the turf. In this way, " run-off " of the fluid was largely prevented, and only $2\frac{1}{2}$ gallons per field were needed as compared with 10 gallons for the original method.

In all, only 27 sites were sampled in 1948, but in 1949 the number was nearly doubled, 47 sites being sampled despite the fact that the South-Eastern Province did not participate. The number of sites was 54 in 1950 and 45 in 1951, the sampling often being done on the same fields each year.

TABLE 1

MEAN NUMBER OF LEATHERJACKETS PER SAMPLING SITE,*† 1948–51

| Province | 1948 | 1949 | 1950 | 1951 |
|---|---|---|---|---|
| Northern ... ... ... ... | (4) 3·0 | (7) 1·1 | (8) 5·8 | (10) 14·7 |
| Yorks and Lancs ... ... ... | (2) 5·0 | (5) 6·4 | (5) 28·2 | (5) 128·2 |
| East Midland ... ... ... ... | (2) 0·7 | (5) 1·3 | (5) 10·9 | (3) 91·7 |
| West Midland ... ... ... | (2) 1·3 | (6) 5·1 | (5) 11·7 | (6) 22·6 |
| Eastern ... ... ... ... | (2) 2·9 | (5) 13·8 | (5) 55·6 | (5) 47·2 |
| South-Eastern (Reading) ... ... | (2) 0·4 | — — | (5) 2·4 | — — |
| South-Eastern (Wye) ... ... ... | — — | — — | (5) 14·5 | (5) 60·2 |
| South-Western (Bristol) ... ... | (4) 0·4 | (5) 4·7 | (5) 17·5 | (5) 84·2 |
| South-Western (Starcross) ... ... | (2) 6·7 | (6) 8·2 | (6) 16·4 | (3) 48·7 |
| Wales ... ... ... ... ... | (7) 5·8 | (8) 15·3 | (5) 19·5 | (6) 47·2 |

* The means are for 20 sq. ft. every year. † Figure in brackets is number of sites.

In 1948 it appeared that leatherjackets were most numerous in the Wales and the Starcross section of the South-Western Province, and lowest in the South-Eastern and Midland Provinces and the Bristol section of the South-Western Province. This pattern of distribution was not maintained in the later years of the survey. Judging from the reports of advisory entomologists from the country as a whole, leatherjacket damage occurs more frequently in the western areas of the country, and there may be a connection between the heavier rainfall in the west and the establishment and maintenance of leatherjacket populations.

## FORECASTING CROP INJURY

The data in Table 1 can be simplified further by bulking all the figures to give an indication of the mean number of leatherjackets per site each year for England and Wales as a whole. This "National Index" figure was 3·3 in 1948, 8·4 in 1949, 15·6 in 1950, and 53·8 in 1951. No attempt has been made to attach an absolute value to this index. It does, however, indicate trends, and it suggests that over the period 1948–51 leatherjackets were probably on the increase not only in individual provinces, but in the country as a whole.

The 1948 sampling results showed relatively few leatherjackets, and subsequent reports of injury were about normal. In 1949 there was an increase in leatherjacket populations in most parts of the country (Table 1), the "National Index" being more than twice that in 1948. From this I forecasted a danger of widespread leatherjacket damage in 1950, and subsequent reports showed that leatherjacket damage was indeed widespread and often serious in that year.

The sampling in 1950 indicated that leatherjackets were in fact much more numerous than in 1949, the increases ranging from a 25 per cent increase in Wales to a 500 per cent increase in the Northern Province. These increases reflected not only the greater numbers of leatherjackets in April 1949, but also the mass emergence of Crane flies in August and September 1949, when the insects were so numerous in some areas as to be a nuisance. The "National Index" for 1950 was nearly twice that for 1949, and it was forecast that there was a real danger of leatherjacket populations in 1951 being as high or higher than they were in 1950. This forecast proved accurate, there being an abnormally high number of cases of severe leatherjacket injury to crops reported by the N.A.A.S. entomologists.

The "National Index" rose from 15·6 in 1950 to 53·8 in 1951, and Crane flies were again extremely numerous in the autumn of 1951. Conditions for ovipositing were very favourable and, although the first half of October 1951 was abnormally dry, soil conditions were not unfavourable for the early instar larvae. In the Northern Province some leatherjacket sampling was done in October 1951, and the figures showed that populations were up to three times greater than those recorded on the same sites in 1951.

As a result of the 1951 sampling it was forecast that unless there was a high degree of mortality in the winter there was a likelihood of leatherjackets being abundant in the spring of 1952. This could only be confirmed by spring sampling, but it was suggested to advisory officers that immediate warning be given of the danger to crops on ploughed-out grass and leys so that adequate stocks of Paris green and substitutes such as wettable DDT powder could be secured. Subsequent reports showed that damage was on a higher level in 1952 than in any of the previous six years, and a wide variety of crops were damaged (see *Plant Pathology*, 1952, **1**, 136).



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### INDICATIONS FOR FUTURE WORK

The technique of sampling for leatherjackets used during the past four years has been of value in indicating levels of populations, even though soil and weather conditions greatly influence the results. An increased number of sites would give a clearer national picture, and would certainly enable much better estimates of risks of damage to be made in individual provinces. Observations made in the Northern Province in the autumn of 1951 and 1952 indicate that there is a possibility of using the technique well before spring crops are sown. It might even be possible, in time, to estimate populations in the autumn; warnings could then be issued to farmers some months in advance of the time when damage is likely to occur.

## EXPERIMENTS ON THE CONTROL OF CABBAGE ROOT FLY

*by* B. D. MORETON, W. I. ST. G. LIGHT AND M. E. JOHN

*National Agricultural Advisory Service, Wye, Kent*

Pilot experiments were carried out at Peacehaven in Sussex and at Higham in Kent, in 1952, to investigate the concentration of a number of modern insecticides required for effective control of Cabbage Root fly (*Erioischia brassicae* Bouché) when used in root dips or in spraying along the rows. Special attention was paid to the reduction of stand by root damage when the materials were used at too high a concentration, and to the relative costs of the treatments.

### ROOT DIP TREATMENTS

In a randomized block trial at Peacehaven, Primo-type cabbages were dipped up to the lower leaves in suspensions of gamma–BHC, dieldrin and toxaphene wettable powders each at 10, 5, 1 and 0·5 per cent concentration of toxicant, and planted out on May 27 immediately after dipping. In each plot a single row of 16 plants was allotted to each of the four concentrations, the treated rows alternating with untreated control rows. There were three replications of each treatment. Controls were dipped in water. The soil was very dry, and as the field suffered from drought during the summer, root injury by the chemicals was probably as high as is likely to be encountered in practice. The eventual root fly attack on the controls was severe.

By four weeks after planting out only a moderate attack of root fly had developed, but the 10 per cent dips had caused a check to growth through root injury, which was severe with the gamma–BHC but less severe with dieldrin and toxaphene. The plants treated with the 5 per cent dips were moderately checked, and, like the control rows, they were irregular in growth, while those treated with the 1 and 0·5 per cent dips of all three of the insecticides showed consistently good growth.

On August 7, when harvesting had been completed, a count was made of cut stumps to give a record of the number of marketable cabbages. All the stumps

in the 1 and the 0·5 per cent treated rows, and a proportion of those in the untreated rows, were lifted and the roots examined for Cabbage Root fly injury.

TABLE 1

RESULTS OF ROOT-DIPPING TRIAL FOR THE CONTROL OF CABBAGE ROOT FLY ON PRIMO CABBAGE, 1952

| | Mean Percentage of Marketable Cabbages | | | | Percentage of Roots Attacked by Root Fly | | | |
|---|---|---|---|---|---|---|---|---|
| Concentration of Dip, *per cent* | ½ | 1 | 5 | 10 | ½ | 1 | 5 | 10 |
| Gamma–BHC ... ... ... | 94 | 94 | 81 | 40 | 8 | 2 | — | — |
| Dieldrin ... ... ... ... | 83 | 77 | 71 | 28 | 4 | 0 | — | — |
| Toxaphene ... ... ... | 84 | 94 | 86 | 71 | 11 | 8 | — | — |
| Control (water only) ... ... | 64 | | | | 58 | | | |

All the materials gave good control of Cabbage Root fly at 0·5 and 1 per cent concentration. On the treated roots that were examined an occasional single puparium was the only evidence of the pest, while on the untreated roots the injury was severe. The yields were of the same order with all three of the insecticides used as 0·5 and 1 per cent dips; with the 5 per cent dips there was some check to growth and probably a delay in hearting; while with the 10 per cent dips the yields were lowered, almost certainly owing to root injury by the chemicals.

In a small supplementary trial with gamma–BHC only, on duplicated rows of twenty cabbages each, planted out on May 12, there was again a severe check to growth at the highest concentration, the percentage of marketable cabbages being 55, 88, 78, 83, and 60, with dip concentrations of 0 (control), 0·5, 1, 4 and 7 per cent, respectively.

### ROW SPRAYING TREATMENTS

The possibility of obtaining effective control of Cabbage Root fly by spraying insecticide in a narrow band along the rows at the bases of the plants was tested at Higham, Kent, in 1952, on a crop of summer cabbage drilled in March in rows 2 feet apart. Plots were arranged to contain about 200 plants each after singling, and the treatments were replicated three times in randomized blocks. Gamma–BHC, parathion, aldrin and dieldrin, were applied on May 1, immediately after singling and when considerable egg-laying had occurred, at the rates shown in Table 2. Half of each plot was re-treated three weeks later. The application was made by means of a watering can with fine rose to simulate the effect of a spraying machine, and the materials were watered along the rows as evenly as possible in a band about three inches wide. The volumes tried were 10, 5 and 2·5 fluid oz. per yard of row, equivalent to approximately 460, 230 and 115 gallons per acre. The gamma–BHC was in the form of a wettable powder, aldrin and dieldrin were in the form of emulsions. Yields were obtained by counting cut stumps when harvesting was completed. The cabbages were cut when hard hearts about 4 inches in diameter had developed, so that weight was not a consideration. Differences between the once- and twice-treated half plots appeared insignificant. Totals for whole plots are given in Table 2.

The best results with gamma–BHC were obtained with 2·3 lb. of the material in 460 gallons of water per acre, and this was significantly better than the controls



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and the other gamma–BHC treatments, except 2·3 lb. in 230 gallons and 4·6 lb. in 460 gallons. The parathion treatment was ineffective, while aldrin and dieldrin at 2·3 lb. in 230 gallons were as good as gamma–BHC at the same rate of application.

TABLE 2

RESULTS OF ROW-SPRAYING TRIAL FOR CONTROL OF CABBAGE ROOT FLY, 1952

| Treatment | Gallons of Water *per acre* | Amount of Toxicant *lb. per acre* | Yield of Marketable Cabbages *No.* | *Percentage of Original Stand* |
|---|---|---|---|---|
| Gamma–BHC 0·1% ... ... | 460 | 4·6 | 398 | 75 |
| | 230 | 2·3 | 382 | 76 |
| | 115 | 1·15 | 366 | 66 |
| Gamma–BHC 0·05% ... ... | 460 | 2·3 | 425 | 78 |
| | 230 | 1·15 | 343 | 63 |
| | 115 | 0·58 | 323 | 61 |
| Gamma–BHC 0·01% ... ... | 460 | 0·46 | 361 | 69 |
| | 230 | 0·23 | 307 | 62 |
| Parathion 0·025% ... ... | 230 | 0·58 | 276 | 59 |
| Aldrin 0·1% ... ... ... | 230 | 2·3 | 406 | 74 |
| Aldrin 0·05% ... ... ... | 230 | 1·15 | 384 | 72 |
| Dieldrin 0·1% ... ... ... | 230 | 2·3 | 425 | 78 |
| Dieldrin 0·05% ... ... ... | 230 | 1·15 | 377 | 71 |
| Control (untreated) ... ... | — | — | 292 | 57 |
| Significant Difference (P = 0·05) ... ... | | | 46 | |

The treatments with gamma–BHC at three concentrations and three different volumes per acre were given in the hope of obtaining some indication of the effect of amount of water used, but on this point the results were inconclusive. It would appear that, although the degree of control rose with increasing amounts of gamma–BHC, the effects of increasing the amount, over the range tested, were small. The effect of increasing the volume of water carrier was also small, again over the range tested. It may be concluded that, using the method of application described, about 2 lb. gamma–BHC per acre to a crop with rows 2 feet apart would give the maximum control. It is uncertain whether this amount would be best applied with water in the neighbourhood of 460 or 230 gallons per acre, and not known whether it would be sufficiently effective in lower volumes. The control obtainable is not as high as is possible with spot-watering treatments, and the cost of materials is great.

### RELATIVE COST OF ROW SPRAYING AND ROOT DIPPING

As shown above, the amount of gamma–BHC required for row spraying would be about 2 lb. per acre, costing nearly £10 for materials alone. In the root-dipping treatment it was found that the amount of fluid retained by the roots after dipping was about 1 cc. per plant, so that one gallon of dip should be sufficient for 4,000 to 5,000 plants. With about 22,000 cabbages per acre, and a 0·5 per cent dip, the amount of gamma–BHC required would be about a quarter of a pound per acre, costing about 24*s*. The corresponding cost using 0·5 per cent toxaphene would be between 4*s*. and 5*s*.

Thanks are due to Mr. Grant Currie of Peacehaven, and Mr. B. Batchelor of Whitehouse Farm, Higham, with whose co-operation these trials were made.

# COLLAR ROT OF APPLE TREES IN ESSEX

*by* H. C. SMITH

*Botany School, Cambridge*

In June 1952, I examined some apple trees in an orchard at South Benfleet, Essex, in connection with an investigation on root rot caused by *Armillaria mellea*. *Armillaria* was present in the orchard and a number of the trees had died, but the symptoms on affected trees were unlike those usually caused by *Armillaria*. There was a rotting at the base of the trunks, from which the trees were said to have been suffering for the past nine years, and this resembled the collar rot due to *Phytophthora cactorum* (Leb. & Cohn) Schroet., which has been described from Indiana by Baines (1939), from British Columbia by Welsh (1942) and from New Zealand by me (Smith, 1950). On microscopic examination, mycelium resembling that of *Phytophthora* could be seen in the tissues of the advancing margin of active lesions, and from one such lesion *P. cactorum* was isolated. This fungus has been recorded as causing rotting of apple fruits (Wormald, 1939), but it does not appear to have been previously recorded as attacking the bark of apple trees in England.

The first symptoms of the disease, as they were seen in the orchard and described by the grower, were typical of those occurring in America and New Zealand. There was a gradual decline in vigour of one or more leaders or main branches, with leaves and fruit small and highly coloured, and usually falling prematurely in the autumn. The rate of decline and death of the trees was very variable, sometimes occurring within a single season, sometimes lingering over a number of years. When the base of the trunk and the crown roots were exposed the bark was found to be rotting in irregular areas. In the early stages only the base of the trunk was affected, but in a more advanced stage the lesion extended round the trunk, upwards towards the main leaders, and downwards along the crown roots. Extensive lesions on the trunks were found only on Cox's Orange Pippin, but root infection was present on a number of varieties. The rotted areas were not immediately visible to the naked eye, but when the surface corky layer was removed from bark recently invaded by *P. cactorum*, the cortex was seen to be reddish brown in colour. The tissues later turned black and became soft and rotten, especially when below ground level.

## ISOLATION OF THE FUNGUS

Pieces of bark from the margins of actively spreading infections were kept moist on removal from the tree, washed vigorously in running water, and then pressed between sterile filter paper to remove excess moisture. Small portions of the apparently healthy bark adjacent to the discoloured edge of the lesion were then cut out and pressed into sterile water agar. Irregular, sparse hyphae, growing out after incubation, were transferred to potato dextrose agar. Attempts to isolate *P. cactorum* from old infections and from roots were unsuccessful, probably because the mycelium of the fungus is rapidly attacked and disintegrated by bacteria very closely behind the advancing edge of the rot. The isolate obtained from the Cox's Orange Pippin in Essex grew very slowly at 30° C. and was similar in appearance and growth rate to isolates causing trunk canker of apple trees in New Zealand. The sporangia were markedly papillate and were formed abundantly on the potato dextrose agar. Oogonia, with paragynous antheridia, were also produced abundantly. The oospores almost filled the oogonia and averaged 25$\mu$ in diameter.

### INOCULATION EXPERIMENT

Wound inoculations were made by inserting 7 mm. squares of potato dextrose agar culture beneath the bark of Cox's Orange Pippin and Bramley's Seedling trees at the Botany School Field Station, Cambridge. Inoculations, both in the branches and trunks, were made on September 12, 1952, and were covered with petroleum jelly. For comparison, cultures of *P. cactorum* and of *P. cactorum* var. *applanata* from several hosts were also inoculated on the same date. The results, recorded after four months, were as follows :

MEAN AREAS OF LESIONS RESULTING FROM INOCULATION OF APPLE TRUNKS AND BRANCHES WITH CULTURES OF PHYTOPHTHORA CACTORUM AND P. CACTORUM VAR. APPLANATA. CAMBRIDGE, 1952

| *Source of Inoculum* | All Tests *sq. cm.* | *Variety of Apple* | All Tests *sq. cm.* |
|---|---|---|---|
| *P. cactorum*, from : | | Cox's Orange Pippin ... ... | 3·27 |
| Cox's, trunk, Essex ... ... | 5·57 | Bramley's Seedling ... ... | 2·51 |
| Cox's, trunk, N.Z. ... ... ... | 5·05 | | |
| Jonathan, root, N.Z. ... ... | 3·20 | | |
| Pear, fruit, N.Z. ... ... ... | 1·75 | | |
| C.M.I., Kew, Surrey ... ... | 2·05 | *Site of Inoculation* | |
| *P. cactorum*, var. *applanata* | | Trunk ... ... ... ... | 3·45 |
| Lemon, fruit ... ... ... | 2·17 | Branch ... ... ... ... | 2·33 |
| Hops, root, Kent ... ... ... | 2·00 | | |
| *Schinus molle* ... ... ... | 1·35 | | |
| Significant difference (P = 0·01) ... | 1·41 | Significant difference (P = 0·01) | 0·71 |

The trunk bark was more susceptible than branch bark, and the Cox's Orange variety more susceptible than Bramley's Seedling. There were three distinct groups of isolates differing significantly in pathogenicity. The isolate from the trunk of the Cox's Orange in Essex was comparable in pathogenicity with that from Cox's Orange in New Zealand, which had been the most pathogenic of nine isolates tested in New Zealand. The isolate from Jonathan roots in New Zealand was of medium pathogenicity, while the remaining isolates of *P. cactorum*, and all the isolates of *P. cactorum* var. *applanata*, were only slightly pathogenic. Baines (1939) also found such differences in pathogenicity between isolates and suggested the existence of physiologic races of *P. cactorum*. The analysis of variance of the infection data showed a significant interaction between the isolates and the varieties, this indicating that whereas the isolates of *P. cactorum* from the trunks of Cox's Orange were more pathogenic to Cox's Orange than to Bramley's Seedling, the isolates of *P. cactorum* var. *applanata* were probably more pathogenic to Bramley's Seedling than to Cox's Orange.

I thank Mr. B. M. Hodgkin, of the National Agricultural Advisory Service, Essex, and Mr. A. G. Eldridge for their help in this work.

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# CONTROL OF MILLET SMUT WITH FORMALDEHYDE

*by* W. A. R. DILLON WESTON

*National Agricultural Advisory Service, Cambridge*

In earlier trials (Dillon Weston and Schofield, *Plant Pathology*, 1952, **1**, 29–30), it was found that seed treatment by sprinkling with formaldehyde did not give complete control of Smut, *Sphacelotheca destruens* (Schlecht.) Stevenson & Johnson, on Common Millet (*Panicum miliaceum*). This was disappointing and puzzling, as formaldehyde is usually a most effective seed disinfectant when used for killing the spores of parasitic fungi on the surface of grain. As it was thought that the failure might be due to the method of application rather than to the material, a further trial was made in 1952 for comparison of the effects of formaldehyde application as a sprinkle and as a steep.

The seed used was that which had been grown the year before, and it was first damped by keeping it in a saturated atmosphere for 5½ hours at 28° C., and then shaken with the inoculum in a closed jar. For the sprinkling treatment, the seed was sprinkled with the solution—being turned constantly during the process—after which it was covered with a piece of cloth soaked in the solution and left for four hours. In the steeping treatment the seed was placed in muslin bags and immersed in the solution for 5 minutes ; it was then covered as in the sprinkling method and left for four hours. The 40 per cent formaldehyde was used at two dilutions by each method, i.e., at 1 part in 320 and 1 part in 160 of water. At the weaker strength the solutions were used with and without the addition of proprietary spreaders (T and S). A randomized block layout was used for the field trials with seven replications of each of the treatments and control (contaminated seed without treatment). Each plot consisted of a single rod row. The seed was treated on May 14, dried, and sown thickly on the following day.

| Treatment | Percentage Germination | No. of Heads per 7 Rod Rows *Total* | *Smutted* | Mean Percentage Infection |
|---|---|---|---|---|
| Formaldehyde 1 : 320 | | | | |
| Sprinkled ... ... ... | 91 | 5,020 | 587 | 11·6±1·6 |
| Steeped ... ... ... | 94 | 5,022 | 2 | 0·03 |
| Steeped (with spreader T) | 95 | 5,095 | 0 | 0·0 |
| Steeped (with spreader S) | 95 | 4,684 | 4 | 0·08 |
| Formaldehyde 1 : 160 | | | | |
| Sprinkled ... ... ... | 97 | 5,235 | 27 | 0·5 |
| Steeped ... ... ... | 95 | 4,508 | 0 | 0·0 |
| Spreader solution only | | | | |
| Steeped (T) ... ... | 92 | 5,487 | 1,114 | 20·3±1·7 |
| Steeped (S) ... ... | 91 | 5,319 | 1,972 | 37·0±4·7 |
| Control, untreated ... ... | 97 | 5,375 | 2,558 | 47·5±2·9 |

The results, summarized in the table, showed that the steeping treatment with formaldehyde at 1 : 320 was much more effective than the sprinkling treatment, and gave almost complete control. Effective, but not complete control, was obtained by sprinkling with formaldehyde at 1 : 160.

I thank Dr. P. S. Wellington of the Official Seed Testing Station, Cambridge, for the germination tests, and Mr. H. J. Wilcox and Mr. H. W. Wheeler of my staff, for the recording and care of the trial.

# SYMPTOMS OF CAULIFLOWER MOSAIC AND CABBAGE BLACK RING SPOT IN CAULIFLOWER

*by* L. BROADBENT AND T. W. TINSLEY

*Rothamsted Experimental Station, Harpenden, Herts*

During field work on Cauliflower Mosaic and Cabbage Black Ring Spot in England during 1951 and 1952, some experiments and observations were made on factors which affect the symptoms shown by infected plants. Although much work has been done on these two virus diseases, some new facts emerged that warrant recording.

## CAULIFLOWER MOSAIC VIRUS

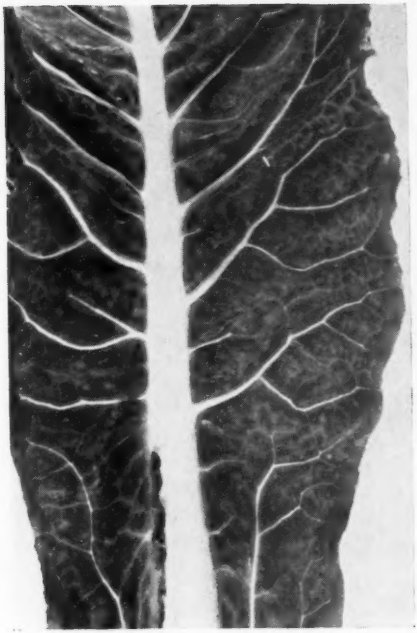
In addition to the typical symptoms of vein-clearing, vein-banding, leaf distortion and " enations ", three other symptoms of the virus occurred in cauliflower. When plants were grown at a low light intensity, discrete chlorotic local lesions sometimes appeared on inoculated leaves (Plate I, 1). Systemically infected leaves occasionally bore chlorotic spots instead of, or in conjunction with, vein-clearing or vein-banding. Many varieties of cauliflower also developed dark necrotic areas and spots, varying from minute specks to areas 3 mm. in diameter, and resembling the symptoms described by van Hoof (1952) in cabbage (Plate I, 4).

Isolates of cauliflower mosaic virus from diseased plants showing different symptoms in the field also caused symptoms of different severity in cauliflower plants infected under glass. Strains causing slight symptoms in cauliflower led to only vein-clearing and slight distortion in turnip, whereas strains that caused severe symptoms in cauliflower killed turnip plants.

Tompkins (1937) stated that the disease starts with vein-clearing on one or several leaves, but that this is gradually replaced by vein-banding. Caldwell and Prentice (1942) also found that vein-clearing in younger leaves slowly gives way to vein-banding, but that vein-clearing could persist in old leaves. We have observed the succession of symptoms in two varieties of winter cauliflower, Extra Early Roscoff and St. George, grown in a glasshouse until symptoms began to appear, and then divided into two batches of five plants each, one batch being put outside. Fully expanded leaves above the inoculated leaves never showed symptoms ; the largest of the incompletely expanded leaves often showed vein-clearing over a part only of the leaf, usually the base ; and these leaves never developed vein-banding. Younger leaves often, but not always, showed vein-clearing as a first symptom, and sooner or later developed vein-banding. Some plants never produced " enations ", some produced them only on the first leaves to show symptoms, others continued to produce them so that " enations " occurred even on leaves developed after plants were systemically infected.

The banding along the veins was always dark green at first, with lighter inter-veinal areas (Plate I, 3), but leaves developed later sometimes had light banding along the veins with darker areas between. The vein-banding on some younger leaves of all the indoor plants faded in late May and June, when the mean temperature over a period of twenty days averaged 25° C. The interveinal areas became dark green, but had lost the waxy " bloom " ; this was retained by the bands along the veins, which became dark metallic blue. Some leaves ultimately became indistinguishable from uninfected leaves, and usually remained

1. Cauliflower Mosaic : chlorotic local lesions.



2. Mottle : Cauliflower Mosaic plus Cabbage Black Ring Spot.

3. Cauliflower Mosaic : vein-banding.

4. Cauliflower Mosaic : necrotic stipple.

*Photos : Rothamsted Experimental Station*

PLATE I



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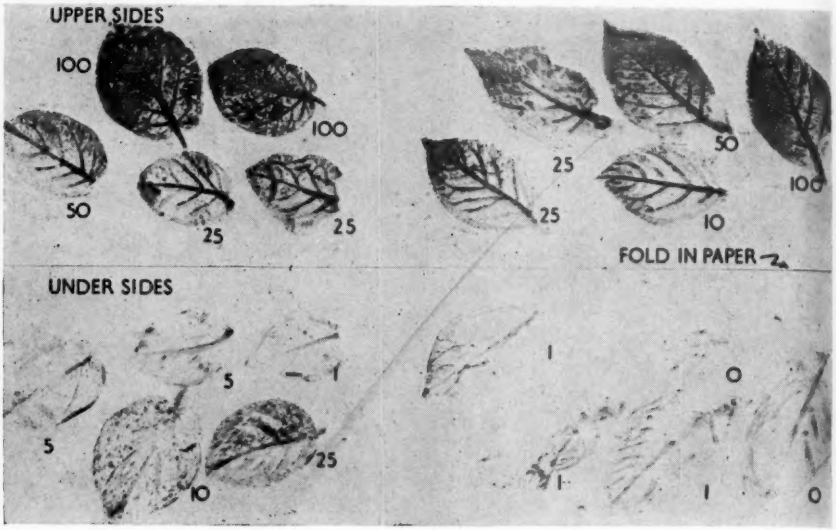
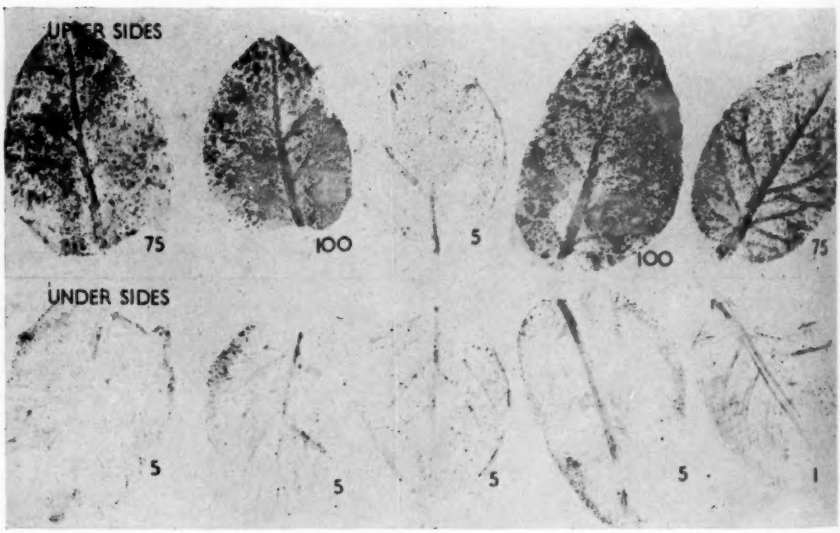
SPRAYING FROM ABOVE ONLY
Method E. Fig. 1. P. 94.




Leaflets from upper parts of plants.

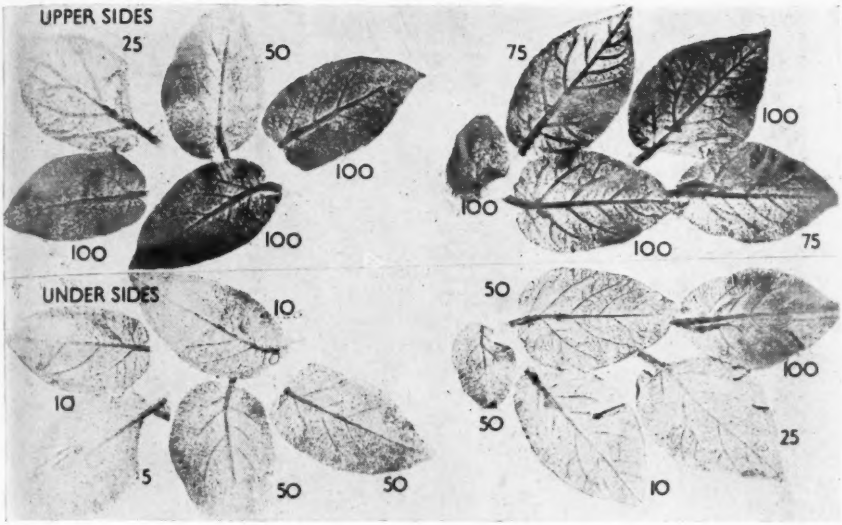



Leaflets from lower parts of plants.

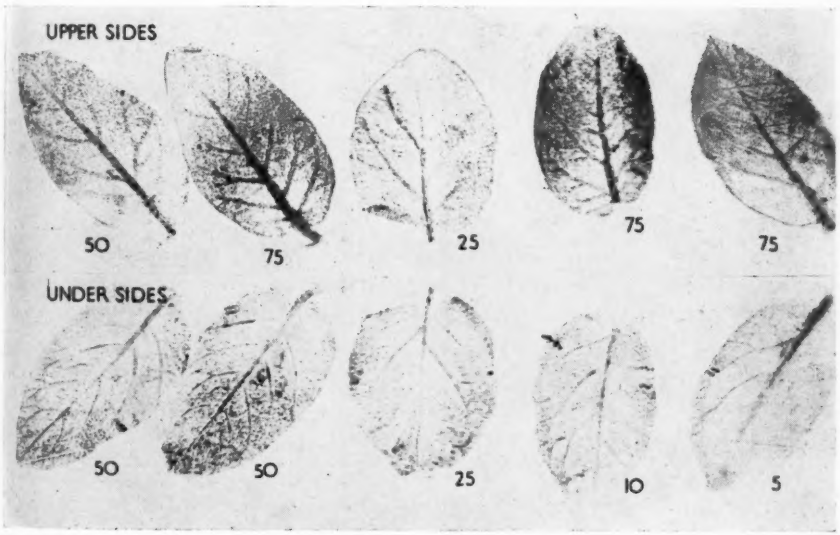
When the spraying was done from above only, without drop lances, good cover was obtained on the upper surfaces of both upper and lower leaves but little or no cover of under surfaces. With size 0 Fan-jet nozzles at 50 lb. per sq. inch the spray was relatively coarse.

PLATE II

SPRAYING FROM ABOVE AND BELOW
Method B. Fig. 1. P. 94.




Leaflets from upper parts of plants.




Leaflets from lower parts of plants.

When spraying was done from above and below, with drop lances, there was considerable cover of the under surfaces of the leaves as well as of the upper surfaces. With Bray 000 nozzles at 100 lb. per sq. inch pressure, the spray was relatively fine.

PLATE III

Plant of *Gypsophila paniculata* L. " Bristol Fairy " infested with Stem and Bulb eelworm, *Ditylenchus dipsaci* (Kühn) Filipjev.

*Inset* : Eelworms and eggs in gypsophila seedling (stained with Flemming's solution). ×11.

PLATE IV

so, even when put outside at lower temperatures for two weeks. All the leaves which had developed symptoms at low temperatures retained them during hot weather. Young leaves produced at high temperatures always showed symptoms at first, though these soon became masked. The outdoor plants showed symptoms throughout the period.

### CABBAGE BLACK RING SPOT VIRUS

Symptoms were much less variable than in infections with cauliflower mosaic virus. They consisted of chlorotic spots or rings varying from 2 to 5 mm. in diameter, usually raised to form blisters. The spots lacked the waxy " bloom " and were more obvious on the lower than on the upper surfaces of the leaves. The spots were usually few and discrete, but sometimes were so numerous that they merged to form an indistinct mottle. On older leaves they were occasionally necrotic. Turnips were more affected than cauliflowers by cabbage black ring spot virus ; some strains caused only pale blisters and blotches, but others considerably distorted the leaves, and soon killed them.

When cauliflower plants were infected simultaneously with Cauliflower Mosaic and Cabbage Black Ring Spot, early symptoms of both appeared, but soon were obscured by generalized mottles (Plate I, 2).

### TIME OF APPEARANCE OF SYMPTOMS

Pound and Walker (1945 a and b) found that cauliflower mosaic virus causes symptoms sooner in inoculated cabbage plants at 24° or 28° C. than at 16° or 20° C., but that symptoms are more severe at the lower temperatures. At both 16° C. and 28° C. symptoms of Cabbage Black Ring Spot are less severe, and those of Cauliflower Mosaic more severe, under short-day (8-hour) than long-day (15-hour) exposures. The cabbage black ring spot virus also causes symptoms more rapidly at high temperatures, but the symptoms are less severe at low than at high temperatures.

Our observations on plants grown under glass at different times of the year were in agreement with the conclusions of Pound and Walker. Table 1 shows the average and the range of time taken for initial symptoms to appear in plants inoculated with the two viruses.

TABLE 1

PERIODS BEFORE APPEARANCE OF SYMPTOMS AFTER INOCULATION WITH CAULIFLOWER MOSAIC AND CABBAGE BLACK RING SPOT VIRUSES*

| TIME OF INOCULATION | MEAN TEMPERATURE | CAULIFLOWER MOSAIC VIRUS | | | CABBAGE BLACK RING SPOT VIRUS | | |
|---|---|---|---|---|---|---|---|
| | | No. of Plants | No. of Days before Appearance of Symptoms | | No. of Plants | No. of Days before Appearance of Symptoms | |
| | °C. | | *Range* | *Mean* | | *Range* | *Mean* |
| November–February | 17·7 | 53 | 15–41 | 25 | 37 | 12–35 | 19 |
| March–October ... | 23·9 | 266 | 11–28 | 18 | 161 | 9–25 | 14 |
| Mean ... ... | 21·9 | 319 | 11–41 | 19 | 198 | 9–35 | 15 |

* Extra Early Roscoff cauliflower, inoculated in 3–5 leaf stage, 1951–52.

Observations on plants in field crops suggested that during spring and summer symptoms appeared within 2–4 weeks of infection, and that when infections occur in the late autumn, symptoms often fail to show until the plants start to grow again in the spring.

Symptoms not only appeared sooner at higher temperatures, but they went through the various phases more quickly when the plant was growing rapidly. Fig. 1 illustrates this effect: 48 winter cauliflowers were inoculated in the 3–4 leaf stage and kept under glass until symptoms began to appear, when 24 were put outside. After one week, 12 of the plants outside were exchanged for 12 of those inside, and after a further 10 days these two batches were again changed. Mean temperatures over the period were 20° C. inside the glasshouse, and 7° C. outside. The succession of symptoms on each leaf of each plant was noted and their severity recorded on an arbitrary numerical scale.* The plants which were inside all the time grew more rapidly and vein-banding symptoms appeared within 14 days of their first showing vein-clearing, whereas symptoms on plants outside all the time had developed little in 24 days. Moving the plants inside or outside increased or decreased both the growth of the plants and the extent to which they showed symptoms.

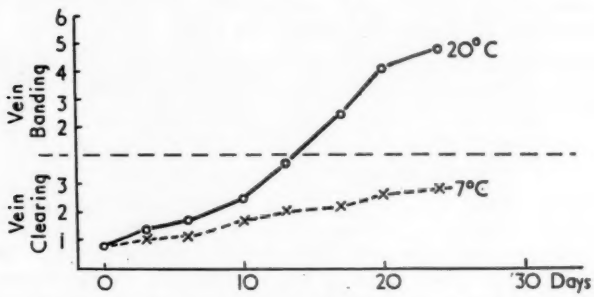



**Fig. 1. Effect of temperature on development of Cauliflower Mosaic symptoms.**

Cauliflower Mosaic is masked when the plants are grown at temperatures above 24° C. Such temperatures are rare in Britain, except for very short periods, and heat-masking has not been noticed in field plants during summer. During winter, symptoms of infection often become indistinct and may be completely obscured by frost damage.

Symptoms of both diseases developed more slowly in old than in young plants. When batches of 10 Extra Early Roscoff cauliflower plants with 3 and 6 leaves were inoculated, symptoms first appeared as follows:

| | Days after Inoculation | No. of Plants showing Symptoms 3-*leaf plants* | 6-*leaf plants* |
|---|---|---|---|
| Cauliflower Mosaic ... ... ... | 17 | 3 | 0 |
| | 19 | 6 | 0 |
| | 23 | 10 | 6 |
| | 27 | — | 10 |
| Cabbage Black Ring Spot ... ... | 9 | 7 | 1 |
| | 12 | 10 | 8 |
| | 16 | — | 10 |

* VEIN-CLEARING, youngest leaf ... ... 1 VEIN-BANDING, 1st leaf ... 1
2nd and 3rd leaves ... 2 2nd leaf ... 2
general ... ... 3 3rd leaf ... 3, etc.

## Virus Disease Symptoms in Cauliflower

Inoculation of young leaves not only resulted in more transmission, but symptoms appeared sooner than when old leaves were inoculated. In one experiment cauliflower plants with 5–6 leaves were divided into four batches; the first and second, or fifth and sixth leaves from the top were then mechanically inoculated, with the following results :

| Days after Inoculation | No. of Successful Transmissions | | | |
|---|---|---|---|---|
| | Cauliflower Mosaic Virus | | Cabbage Black Ring Spot Virus | |
| | *leaves* 1 *and* 2 | *leaves* 5 *and* 6 | *leaves* 1 *and* 2 | *leaves* 5 *and* 6 |
| 12 | — | — | 1 | — |
| 14 | 1 | — | 3 | — |
| 17 | 4 | 1 | 6 | 3 |
| 21 | 7 | 1 | 6 | 3 |
| No. of Plants Inoculated ... | 8 | 8 | 8 | 8 |

Under glass, shade (produced by a cage covered with two layers of muslin) retarded the development of the symptoms of both diseases.

The absence of symptoms in the leaves immediately above those inoculated suggested that the virus does not move into them but moves to the growing point and into each leaf as it develops. No virus could be found in leaves without symptoms, and transmission tests showed that neither virus enters fully expanded leaves unless they are inoculated.

## Influence of Manuring on Symptoms

The influence of fertilizers on symptom expression was tested with Extra Early Roscoff cauliflowers inoculated with cauliflower mosaic virus. The plants were raised in potting soil and transplanted to large glazed pots containing 32 lb. of a mixture of poor soil with 10 per cent sand added and the required amounts of fertilizers. The pots were placed outside in randomized positions and watered daily ; enough water was given to keep the soil moist, but not for leaching to occur. All the pots had a basal dressing of 2½ grammes " Nitro-Chalk " (N1), 2 grammes superphosphate (P1) and 1 gramme sulphate of potash (K1). Some of the pots, in accordance with the factorial design of the experiment, had, in addition, 4½ grammes " Nitro-Chalk " in the soil, plus 7 grammes on July 4 and 6 grammes on August 3 as top dressings (N2), as well as 10 grammes superphosphate (P2) and/or 5 grammes sulphate of potash in the soil (K2). The treatments, each replicated three times, were :

| | | | |
|---|---|---|---|
| N1 P1 K1 | N1 P1 K2 | N1 P2 K1 | N1 P2 K2 |
| N2 P1 K1 | N2 P1 K2 | N2 P2 K1 | N2 P2 K2 |

Symptoms were recorded leaf by leaf at weekly intervals, and later were allotted scores as follows :

| | |
|---|---|
| Mild vein-clearing, mild mottle or " enations " ... ... ... ... | 1 |
| Severe leaf distortion ... ... ... ... ... ... ... ... | |
| Moderate vein-clearing or mottle ... ... ... ... ... ... | 2 |
| Severe vein-clearing or mottle ... ... ... ... ... ... ... | 3 |
| Indistinct vein-banding ... ... ... ... ... ... ... ... | 4 |
| Moderate vein-banding ... ... ... ... ... ... ... ... | 5 |
| Very distinct vein-banding ... ... ... ... ... ... ... | 6 |

After the end of August all the plants showed signs of nitrogen deficiency. They failed to curd adequately, but over the period when growth was vigorous (from June 26 to August 11), the mean effects for additional N, P and K, based on the total scores per plant, were as shown in Fig. 2. Nitrogen significantly increased the rate at which symptoms developed and also their severity; phosphate significantly depressed symptoms, and potash had no significant effect.

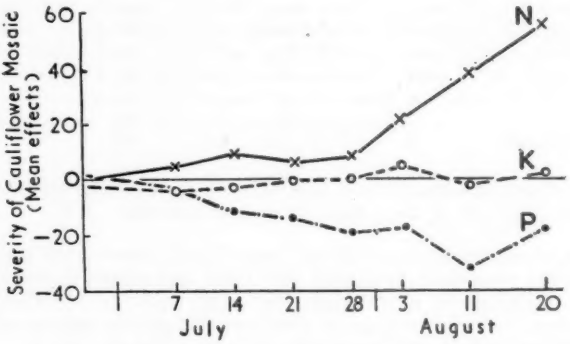



Fig. 2. Effect of fertilizers on appearance of symptoms of Cauliflower Mosaic in Extra Early Roscoff cauliflower. Pot experiments, 1951.

We are indebted to Mr. K. E. Haine of the National Institute of Agricultural Botany for supplying Extra Early Roscoff cauliflower seed from a single parent plant; to Dr. D. J. Watson, of Rothamsted, who allowed the fertilizer experiment to be done in his department under the supervision of his staff, and to Mr. V. Stansfield for the photographs.

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# THE DISTRIBUTION OF SPRAY DEPOSITS IN LOW-VOLUME POTATO SPRAYING

*by* E. C. LARGE

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Much progress has been made in recent years in the development of " low-volume " sprayers—notably for the application of weed-killers on corn crops. These sprayers, applying from 6 to 30 gallons of spray fluid per acre, are commonly tractor-mounted ; they may be of relatively light and simple construction, and thus enable spraying to be done expeditiously and with a minimum of water haulage. The possibility of making a wider use of such machines for potato spraying is obviously attractive ; but before this can be done to the best advantage some study is needed of the degree of cover obtainable on both the upper and under surfaces of the leaves with differing nozzle equipments, and differing arrangements of the spray boom and lances.

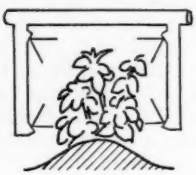
To obtain such information for the particular case of potatoes at an early stage of growth, at which precautionary spraying with DDT against Colorado beetle may be required, a trial of a number of methods of low-volume spraying was organized at Tangmere in Sussex in 1952. In this trial one of us (E.C.L.) studied the distribution of the spray deposits by a leaf-printing method when a copper spray material, as used for Potato Blight, was included in the test fluid ; while the other (G.G.T.) studied the initial amount of the deposits, and of the residues after weathering where DDT was used. The two studies were complementary : the copper leaf prints showed the degree of cover of both the upper and the lower surfaces of the leaves, but not the amount of the deposits ; the DDT estimations showed the amount of DDT on the leaves, but not whether it was on the upper or the lower leaf surfaces.

Machines taking part in the trial were the " Agro " and the " Cropguard " sprayers (Ransomes, Sims & Jefferies, Ltd., Ipswich) ; the "Allman Universal" sprayer (E. Allman & Co., Ltd., Chichester) ; the " Dorman " sprayer (Dorman Sprayer Co., Ltd., Cambridge) and the " Fortemist " sprayer (E. A. Gardner & Sons, Ltd., Maidstone). All the sprayers were tractor-mounted. With the exception of the " Agro " machine having nozzles in which atomization of the spray was effected by air blast, any of the machines could be fitted with the nozzle equipment on any of the others ; for this reason, and with the goodwill and co-operation of all the firms concerned, the several machines were used on the field to try as wide a range of methods as possible. In this account of the work, therefore, results obtained with the differing nozzle equipments will be given without reference to the particular machines on which they happened to be fitted on the occasion of the trial.

## METHODS OF SPRAYING TESTED

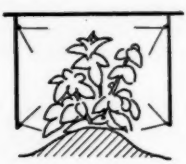
The plants (chiefly Arran Banner but with some Home Guard) on which the trials were made were in bud and not yet meeting across the drills. They had been earthed up, and stood from 15 to 18 inches high above the ridges. The crop was gappy, but the plants adjacent to the gaps were avoided when taking leaf samples. The position of the nozzles in relation to the plants, in each method of spraying tested, is shown in Fig. 1.

One plot, approximately 275 yards long and 40 drills wide, was sprayed by each method. One half of each plot was sprayed with a cuprous oxide spray material (to give about 3 lb. Cu per acre) on July 9, 1952; the other half with a water dispersion of DDT (to give about 1 lb. DDT per acre) on July 10, 1952. On both days the weather was fine, with no rain. Spray drift was apparent but not excessive. The area actually sprayed by each method was measured, and the precise amount of spray fluid applied was obtained by measuring the volume of the fluid put into the sprayer tanks and subtracting that left after the run. The setting of the machines was the same for the DDT application as for the copper.



A. WITH DROP LEGS. AIR BLAST NOZZLES
4 air blast nozzles per row; 2 above foliage, 2 at base of plants. Spraying at 4·4 miles per hour. 10–11 gallons per acre.

B. WITH DROP LANCES. FAN NOZZLES
3 Bray 000 nozzles per row, one centrally above plants, one on either side at base, giving a fogging effect at 100 lb. per sq. inch pressure. Spraying at 3·4 miles per hour. 19–21 gallons per acre. (See Plate III)



C. WITH DROP LANCES. SWIRL NOZZLES
4 swirl nozzles (2/64 inch discs) per row, one on either side above plants, one on either side at base, giving cones of spray at 40–50 lb. per sq. inch pressure. Spraying at 3·1 miles per hour. 15–18 gallons per acre.

D. WITHOUT DROP LANCES. FAN NOZZLES
2 Tee-jet 15/40 nozzles per row, at 14-inch spacing along straight boom, sweeping plants with fan-shaped sprays at 50 lb. per sq. inch pressure. Spraying at 4·6 miles per hour. 26–29 gallons per acre.

E. WITHOUT DROP LANCES. FAN NOZZLES
About 1½ Fan-jet Size 0 nozzles per row; above plants only, at 18-inch spacing along straight boom, sweeping plants with fan-shaped sprays, at 50 lb. per sq. inch pressure. Spraying at 3·2 miles per hour. 26–27 gallons per acre. (See Plate II)

**Fig. 1. Arrangement and particulars of nozzles used in five methods of low-volume spraying tested at Tangmere, 1952.**

### SAMPLING OF THE SPRAYED FOLIAGE

For tests of distribution of the copper spray by the leaf-printing method, two samples of 50 entire (compound) leaves were taken from both the upper and the lower parts of the plants in each plot as soon as the spray deposits were quite dry. The leaves were taken at random over the middle third of the length of the sprayed drills, one sample from those sprayed on the outward run of the machine, and the other from those sprayed on its return. The sample leaves were tied in bundles and labelled in the field, and then taken back to the laboratory in large, waxed paper bags, using one bag for the samples for each treatment.

For the DDT estimations, samples were taken separately from four rows in each plot by punching discs from one hundred leaflets per sample taken at random from the fully grown lower foliage. A further series was taken from the upper foliage. In taking the lower foliage an attempt was made to restrict the sample to mature leaves which were protected by other leaves from above and from the sides. Samples from upper foliage were taken from mature leaves which were fully exposed to spray as applied from above.

### ESTIMATION OF COVER BY COPPER DEPOSITS

Prints of the spray deposits were obtained by placing leaflets between folds of foolscap duplicating paper moistened with a rubeanic acid solution prepared as described below, and then running a photographic roller-squeegee once over the fold, with a piece of flannel above and below it to equalize the pressure. The sheet of duplicating paper was folded lengthwise along its centre line, so that when it was opened out after the rolling, prints of the upper leaflet surfaces appeared on the upper half of the sheet, and of the lower leaflet surface on the lower half. Ten of the smaller leaflets from the upper parts of the plants, or five of the larger leaflets from lower leaves, were printed on each foolscap sheet (Plates II and III).

The rubeanic acid solution was prepared by dissolving 0·1 grm. of rubeanic acid (dithio-oxamide) in 180 ml. of water with 9 ml. of glacial acetic acid at 70° C., and then adding 100 ml. ethyl alcohol (industrial spirit) after cooling. The solution was freshly made up within a few days of its use as it decomposes on keeping. The degree of moistening of the paper found best for the printing was that obtained by soaking one sheet in the solution and then blotting it with another. A single firm stroke of the squeegee over the fold was sufficient : repeated rolling, or leaving the leaflet too long in contact with the paper, resulted in a diffusion of the colour round the points of contact with the deposits. The grey colour of the prints developed quickly on exposure, and was permanent after air-drying of the paper. The method is a very sensitive one for revealing the presence of even faint traces of copper on the leaves. In preliminary experiments it was found that the presence of 0·2 milligrams of copper per sq. inch of leaf surface gave a deep grey stain on the print, while even as little as 0·0002 milligrams per sq. inch gave a stain that was still clearly perceptible.

In assessing the coverage by spray deposits, one hundred spots per sq. inch, each of about 1 mm. in diameter (or any spotting or spattering denser than this) was taken as 100 per cent cover. By visual judgement each leaflet print was then given a mark of 0, 1, 5, 10, 25, 50, 75, or 100 per cent according to the proportion of the surface " covered ". Plates II and III show a few of the leaflet prints with differing degrees of cover and their marking.

The degree of cover varied greatly from leaf to leaf with all methods of spraying. To obtain any fair indication of it over the foliage as a whole, it was therefore necessary to print a large number of leaflets for each treatment and to proceed on a statistical basis. Each sub-sample for cover estimation was of 50 leaflets, taken from 10 whole leaves extracted at random from the plot sample. In all, 4 lots of 50 leaflets, from the upper and also from the lower parts of the plants, were printed and marked for each method of spraying. The mean assessments are given in Table 1, together with the standard errors of the means, which provide a measure of the variation in cover from sample to sample of 50 leaflets. Subsidiary tests showed that only a little decrease in the standard error could be obtained by taking more than 4 sub-samples of 50 leaflets for printing, but that the results of assessments on only one or two lots of 50 leaflets could be very misleading.

TABLE 1

COVERAGE OBTAINED IN SPRAYING POTATO FOLIAGE BY SEVERAL METHODS OF LOW-VOLUME APPLICATION. TANGMERE, JULY 9, 1952
(Plants 15–18 inches high, not yet meeting across drills)

| METHOD OF SPRAYING* | GALLONS PER ACRE | MEAN PERCENTAGE COVER | | | |
|---|---|---|---|---|---|
| | | Top Leaves | | Lower Leaves | |
| | | *Upper Surface* | *Lower Surface* | *Upper Surface* | *Lower Surface* |
| A. With drop legs. Air-blast nozzles. | 11½ | 48±4 | 44±5 | 44±4 | 38±5 |
| B. With drop lances. Fan nozzles. | 18¾ | 63±5 | 37±3 | 71±2 | 24±2 |
| C. With drop lances. Swirl nozzles. | 18½ | 41±4 | 25±7 | 62±2 | 20±2 |
| D. Without drop lances. Fan nozzles. | 26 | 55±5 | 7±2 | 63±7 | 3±½ |
| E. Without drop lances. Fan nozzles. | 27 | 40±6 | 3±½ | 51±10 | 4±½ |

* See Fig. 1 for arrangement and further particulars of nozzles.

The results indicate that there was no significant difference in the cover of the *upper* leaf surfaces resulting from the different methods of spraying. All the methods were about equally effective in this respect, and with the young plants not yet meeting across the drills, the cover on the upper surfaces of the lower leaves was as good or slightly better than that on the upper leaves.

The cover of the *under surfaces* of the leaves varied greatly according to the method of spraying. When the plants were sprayed from above only (without drop legs or drop lances), the cover of the under surfaces of the leaves, both at the top and at the base of the plants, was practically negligible. Where drop lances or drop legs were used, and the leaves were thus sprayed from below as well as from above, there was a substantial cover of the under surfaces of the leaves, amounting to at least half of that on the upper surfaces.

## DEPOSITS OF DDT ON UPPER AND LOWER LEAVES

Leaf sampling on the half plots sprayed with DDT on July 10 was done not only as soon as the deposits were dry on the day of spraying, but also, on two of the half plots, at 18 and 32 days after the spraying, to obtain information on the reduction of the deposits by weathering. The leaf-discs were placed in

a refrigerator as soon after sampling as was possible, and they were analysed for DDT by a method based on that of Schechter-Haller. Because of the development of interfering colours in this colorimetric method of estimation, the individual analytical results were subject to an error of ± 5 per cent. Table 2 presents the mean deposits found by analysis of four samples from each plot, with standard errors to provide a measure of the variation in the amount of deposit from sample to sample. The actual amount of DDT applied per acre varied from 0·97 to 1·29 lb. in the differing methods of spraying. To facilitate direct comparison, the figures in Table 2 have been reduced to a common basis, and represent the calculated deposits from an application of 1 lb. of technical DDT per acre by each spraying method.

TABLE 2

DEPOSITS OF DDT ON UPPER AND LOWER LEAVES RESULTING FROM SEVERAL METHODS OF LOW-VOLUME APPLICATION. TANGMERE, 1952

(Results are expressed in microgrammes per 100 sq. cm. of leaf)

| METHOD OF SPRAYING* | GALLONS PER ACRE | UPPER LEAVES | | | LOWER LEAVES | | |
|---|---|---|---|---|---|---|---|
| | | On Day of Spraying | After 18 Days | After 32 Days | On Day of Spraying | After 18 Days | After 32 Days |
| A. With drop legs. Air-blast nozzles | 9·8 | 251±32 | 28±3 | 5±2 | 138±38 | 57±7 | 30±1 |
| B. With drop lances. Fan nozzles | 20·8 | 341±10 | 26±5 | 1±1 | 201±26 | 68±11 | 21±4 |
| C. With drop lances. Swirl nozzles | 15·4 | 223±26 | | | 205±30 | | |
| D. Without drop lances. Fan nozzles | 29·0 | 207±24 | | | 93±7 | | |
| E. Without drop lances. Fan nozzles | 25·7 | 326±13 | | | 175±21 | | |

* See Fig. 1 for arrangement and further particulars of nozzles.

The results indicate that the total deposition on the lower leaves was about half that on the upper by all the methods of spraying except C (with swirl nozzles and drop lances) where the deposit on the lower leaves approached equality with that on the upper. Methods B and E with Bray nozzles gave significantly higher deposits on the upper leaves than the other methods. There was also an indication of more even distribution of the spray by these two methods (less variation between the deposits on samples from four different rows). The low deposition, especially on the lower leaves, with method D, may have been due to the fact that this nozzle arrangement was fitted to a boom 30 feet long, spraying 13 rows at a time, while the other arrangements were on shorter booms spraying only 7 or 8 rows at a time. There was a tendency for the long boom to tilt during the spraying so that some of the nozzles were too high above the plants and drift was greater than with the other methods of application.

The loss of DDT from the foliage after 18 and 32 days is clearly shown in Table 2. On the lower leaves about two-thirds of the DDT was lost after 18 days, and this could chiefly be accounted for by the effects of weathering and chemical breakdown. The apparent loss on the upper leaves after the same period was greater, but here new growth contributed to the reduction in the deposits per unit area. After 32 days the effects were still more marked, for the amount of DDT on the upper foliage was then negligible while a considerable amount was still persisting on the lower.

### CONCLUSIONS

In these trials, on young plants not yet meeting across the drills, low-volume spraying from above only gave good cover of the *upper* surfaces of both upper and lower leaves; but substantial cover of the under surfaces of the leaves was obtained only when drop legs or drop lances were used, so that the leaves were sprayed both from above and below.

Cover of the upper surfaces of the leaves only may be sufficient in spraying against the Colorado beetle, which is mobile and a biting insect, but where cover of the undersides of the leaves is desirable, as in spraying against Potato Blight, the need for drop lances is indicated. It may also be that drop lances are necessary to obtain good cover of the *upper* surfaces of the lower leaves after the plants have met across the drills and the upper growth is sheltering the lower. Deposits on the under surfaces of the leaves may be expected to be more persistent than those on the upper surfaces, as the leaf itself protects the deposits from being washed off by rain.

Further trials are needed for the study of the distribution of spray deposits when the potatoes are in more advanced stages of growth, and for the correlation of spray coverage with disease and pest control.

Thanks are due to Mr. R. F. C. Webb of the Ministry's Machinery Division, and to members of the staff of Plant Protection, Ltd., for the organization of the spraying; to Mr. H. R. Heaver of Church Farm, Tangmere, for permitting the trial to be made on his crop; to Mr. J. E. Grose and Mr. I. R. Harrison for technical assistance; and to all the firms, mentioned in the text, who sent machines and operators to take part in the work.

## CAULIFLOWER MOSAIC IN YORKSHIRE, 1950-51

*by* I. F. STOREY AND ANN E. GODWIN

*National Agricultural Advisory Service, Leeds*

A number of broccoli crops in the West Riding of Yorkshire, chiefly in the area between Leeds and Wakefield, were surveyed during late April and May in 1950 and 1951 to determine the extent of infection by cauliflower mosaic virus. The area is one in which the bulk of the crop is cut from mid-May to mid-June; and most of the growers save their own seed from plants selected at cutting time and left to grow on. Thus for some five months in the summer there are often plants of the old and the new crop growing in close proximity.

Counts were made on samples of 100 plants, taken at random in various parts of the fields, and the number of infected plants in each sample was recorded. The number of crops in each of several categories for mean percentage infection is given in the table below.

| Year | Total Number of Crops Surveyed | Number of Crops in Each of Four Ranges of Percentage Infection | | | |
|---|---|---|---|---|---|
| | | 0–30 | 31–60 | 61–90 | 90 *and over* |
| 1950 ... ... ... | 10 | — | 4 | 2 | 4 |
| 1951 ... ... ... | 18 | 6 | 4 | 8 | — |

On two crops at Thornes in 1950, and on most of the crops in 1951, counts were made at varying distances from the edges of the crops to reveal gradients of infection in relation to sources of infection. The five upper diagrams in Fig. 1 show the gradients where infected broccoli crops, seed crops, summer cauliflowers, or brassicas of various kinds in allotments and gardens, were near one edge of the crop surveyed. The pattern of spread of infection into the crop

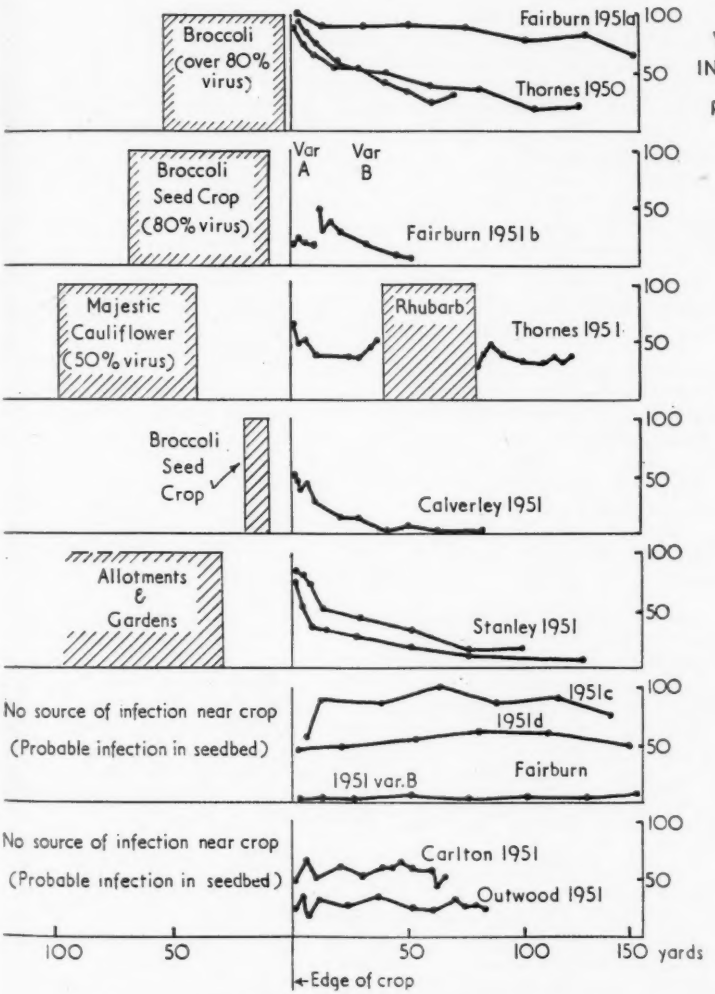



**Fig. 1. Distribution of virus infection in broccoli crops in relation to sources of infection.**

was similar in all these cases; and most of the infection coming into the crop from the neighbouring source appeared to have been taken up by the first fifty rows (about 33 yards). The only exception was at Fairburn (1951a), where the crop was on the site of a seedbed, and where some of the plants had been allowed to grow on to maturity. The lack of any marked gradient here may have been due to secondary spread from the plants first infected.

There was no evidence that size of the virus source was of importance in determining the steepness of the gradient; this point is illustrated by the curve for Calverley in 1951; and it was also found that distances up to fifty yards between the source of infection and the edge of the crop had little effect in reducing the incoming infection, as shown by the curves for Thornes in 1951 and Stanley in 1951. In almost every instance, however, the intervening ground was bare. More difference might be expected with an intervening crop which might have a screening effect. At Thornes in 1951 the crop was divided by a strip of rhubarb, which stood 2–3 feet high—rather above the level of the broccoli. As the curves show, there was some build-up of infection against the rhubarb on the side nearest the Majestic cauliflower, and some sheltering effect on the side away from it.

A difference in varietal susceptibility to infection was shown at Fairburn (1951b), where variety A, nearest to the broccoli seed crop, showed less infection than variety B, which was farther away.

The two lower diagrams in Fig. 1 are for crops where there were no neighbouring sources of infection, but where the plants had been grown in seedbeds alongside maturing broccoli crops, so that many of them were probably infected before planting out in the field. In these circumstances, the virus infection was lowest in the outermost rows and tended to rise towards the middle of the field. Such a distribution was in marked contrast to that where most of the infection came from an outside source. The plants for the crop showing very low infection over the whole field, Fairburn 1951 var. B, were taken from the edge of the field away from the broccoli seed crop at Fairburn 1951b, shown in the diagram above, so that the initial infection was low.

The virus infection in the broccoli crops surveyed in 1951 would appear to have been derived from two sources; that is, first from infection already in the plants when they were taken from the seedbed, and, secondly, from diseased brassica crops in their vicinity after planting out. Both sources are important, but infection in the seedbed would appear to be the more dangerous. Much of the infection coming in after planting out is taken up by the outside rows, and provided that the area is large enough these should not amount to any very great part of the whole. The infection recorded in the crop at Thornes (1951) could well have been derived from both sources, as the level of infection remained high well away from the edge of the field.

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**Long Ashton Research Station, 1903–53**

An account of the origin and history of Long Ashton Research Station, with informative articles on the past and present work of the station on Cider and Fruit Juices, Fruit Culture, Plant Nutrition, Plant Pathology and Food Preservation, was published by the University of Bristol on the occasion of the Jubilee of the station in July, 1953. This commemorative volume of 308 pages with 31 plates, entitled *Science and Fruit* was edited by T. Wallace and R. W. Marsh, and it will constitute one of the important source books for all those interested in the historical development and present organization of agricultural research in Great Britain. It is priced at 30*s*. ($4.50).

# EXPERIMENTS ON CONTROL OF EELWORM IN BLACK CURRANTS

*by* E. B. BROWN

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*Rothamsted Experimental Station, Harpenden, Herts*

As parathion has been found effective in controlling Chrysanthemum eelworm (Dimock and Ford, *Phytopathology*, 1950, **40**, 7), it was considered desirable to try it against Blackcurrant eelworm, which is now considered to be the same species—*Aphelenchoides ritzema-bosi* (Schwartz) Steiner syn. *A. ribes* (Taylor) Goodey.

Twenty severely-affected bushes (var. Daniel's September Black) in an infested six-year-old plantation at St. Albans, were chosen for the experiment; four treatments, each replicated five times, were carried out on June 1, 1951. The treatments were: spraying with 0·025 per cent parathion, at about one-third of a gallon per bush; pruning—the bushes being cut back to leave only the new basal growth; pruning followed by spraying as on the unpruned bushes; and control, without pruning or spraying. Comparable samples of two new shoots and two dead buds were taken from each of the control bushes and from those sprayed without pruning, at intervals from June 7 to July 9, 1951, and the live eelworms were extracted and counted (Table 1). The spraying treatment was repeated on June 25, as live eelworms were then still found in samples from the sprayed bushes.

TABLE 1

EFFECT OF SPRAYING WITH PARATHION ON NUMBER OF LIVE EELWORMS*

| Sampling Date | Untreated Bushes | | Sprayed Bushes | |
|---|---|---|---|---|
| | *New Shoots* | *Dead Buds* | *New Shoots* | *Dead Buds* |
| June 7 ... ... ... ... | 10 | 12 | 0 | 9 |
| June 11 ... ... ... ... | 50 | 6 | 0 | 13 |
| June 14 ... ... ... ... | 105 | 15 | 4 | 4 |
| June 21 ... ... ... ... | 569 | 9 | 4 | 17 |
| July 9 ... ... ... ... | 520 | — | 56 | — |
| Totals ... ... ... | 1,254 | 42 | 64 | 43 |

* The totals given are for 10 shoots or buds in each case, being 2 from each of five bushes.

Analysis of the data summarized in Table 1 showed that the spraying had no significant effect on the number of eelworms in the dead buds; but that it gave a significant reduction in the numbers in the new shoots. The differences were significant on June 7, 11 and 14, but not on June 21 and July 9, despite the second spraying given on June 25, fourteen days before the last count. It would appear that parathion is more effective early in the season than later, possibly because it is more readily absorbed by young than by mature foliage. The apparent ineffectiveness of parathion on the eelworms in the dead buds may be due partly to the difficulty of getting the spray into such buds, and partly to the inability of the dead tissues to absorb the material.

### EFFECTS OF TREATMENTS IN THE FOLLOWING YEAR

To reveal the effects of the pruning treatments, with and without parathion spraying, counts were made of the number of affected branches per bush, on June 1 before treatment, and again on April 28, 1952, eleven months later. The totals for the five bushes for each treatment are given in Table 2.

TABLE 2

EFFECTS OF TREATMENTS ON NUMBER OF AFFECTED BRANCHES

| Sampling Date | Untreated Bushes | Sprayed Bushes | Pruned Bushes | Pruned and Sprayed Bushes |
|---|---|---|---|---|
| June 1, 1951 ... ... ... | 41 | 32 | 30 | 50 |
| April 28, 1952 ... ... ... | 63 | 14 | 7 | 2 |

There was no significant difference in the number of affected branches in the four sets of five bushes on June 1 before treatment. Samples of live shoots taken from the pruned bushes on June 4 yielded a few eelworms, showing that some infestation still remained in spite of severe pruning. An analysis of the data for number of affected branches after eleven months showed that all three treatments gave a significant reduction. There was not enough evidence, however, to show whether pruning and spraying together gave any better control than each separately.

The drastic pruning in June caused the loss of two season's crops from the pruned bushes. If the pruning method were to be adopted in practice it might be made much less severe, but all obviously infested shoots would have to be removed. If such pruning were followed by spraying with parathion a fair measure of control might be achieved without great loss of crop. It would be necessary to prune as soon as eelworm damage became evident in the spring, and to spray as soon as the leaves were fully expanded.

### WEEDS HARBOURING THE EELWORMS

An examination of the weeds growing below the bushes in this trial showed that weeds can play a part in harbouring Blackcurrant eelworms. On April 28, 1952, 85 grammes (fresh weight) of chickweed was removed from beneath the untreated bushes and a similar quantity from beneath the sprayed, unpruned bushes. On soaking, the first sample yielded 302 Blackcurrant eelworms, and the second only 13. On May 6, 1952, after the plantation had been weeded, groundsel and chickweed seedlings about 2 inches high were collected from below the pruned, sprayed and pruned, unsprayed bushes, and counts were made of the Blackcurrant eelworms extracted from them. From the pruned, unsprayed bushes, 12 grammes of weeds yielded 251 eelworms, while from the pruned and sprayed bushes only 3 eelworms were found in 16 grammes of weeds. It would appear that any pruning or spraying treatment should be accompanied by thorough weeding to avoid reinfestation.

We thank Dr. B. G. Peters for statistical examination of the data ; Mr. J. P. Salinger of the N.A.A.S. for finding the trial site, and the Earl of Verulam, Gorhambury, St. Albans, for permission to treat the bushes and for facilities for carrying out the experiment.

# MEDIA FOR THE CULTURE OF *PHYTOPHTHORA INFESTANS*

*by* MARGARET A. KEAY

*Agricultural Research Council, Potato Genetics Station, Cambridge*

*Phytophthora infestans* (Mont.) de Bary does not grow on the usual agar media. The fungus can be kept for several months in tubers stored at 5° C., but such cultures are liable to be invaded by bacteria and other fungi, and in spring and early summer it is difficult to obtain tubers suitable for inoculation. Cultures on the pea-leaf powder medium of Dickinson and Keay (1948) were still pathogenic after three years' storage by the mineral oil method of Buell and Weston (1947), but this medium, like other special media devised from time to time, has not proved to be universally satisfactory.

I have found a medium made from chick-peas (*Cicer arietinum*), first suggested by d'Oliveira and de Moura (1950), to be suitable for the culture of isolates of *P. infestans* originating in Britain, East Africa, Germany and the United States, and its use has largely solved the problem of maintaining stock cultures. Dried garden peas (*Pisum sativum*) are a satisfactory alternative, although sporulation is not so good as upon chick-pea extract. The medium has been slightly modified as a result of experience, and I now prepare it as follows: 250 grm. dried seeds of *C. arietinum* or *P. sativum*; 20 grm. sucrose; 15 grm. agar; 1,000 ml. distilled water. The seeds are washed in tap water for an hour and then soaked in distilled water overnight. The water, reduced in volume by imbibition, is drained off and the seeds mashed with pestle and mortar. *P. sativum* seeds mash less well than those of *C. arietinum*. The mashed seeds, along with the water in which they have soaked—now made up to 1,000 ml.—are steamed for an hour and then strained through surgical gauze. The sucrose and agar, dissolved in a small quantity of water, are then added to the liquor and the whole again made up to 1,000 ml. with hot, distilled water. (If the agar and sucrose are added before the mashed seeds are steamed the mixture tends to froth.) The medium is then tubed in the usual manner and sterilized for 15 minutes at 10 lb. pressure.

I wish to express my thanks to Dr. Maria de Lourdes D'Oliveira for inviting me to co-operate with her in the development of this medium, and for her permission to publish the formula. I also thank Miss B. S. Rogers for technical assistance.

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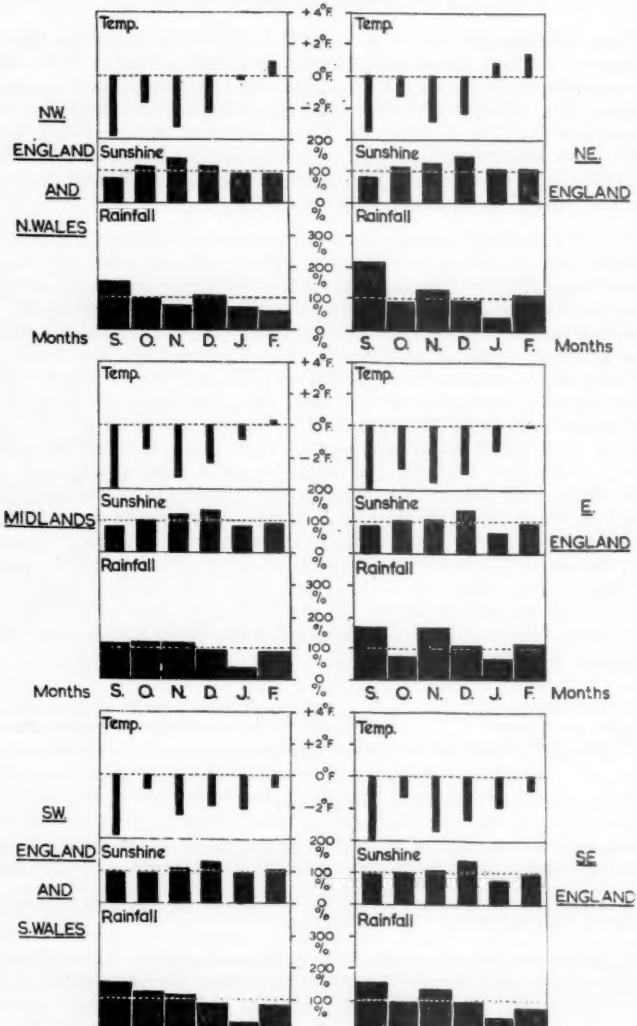
SEPTEMBER–FEBRUARY WEATHER 1952–53

Variations from average



# THE WEATHER OF ENGLAND AND WALES*

## AUTUMN AND WINTER, 1952-53

In contrast to the previous year, the autumn months of 1952 were unusually cold and the first autumn frosts were much earlier than normal. In several places the average temperature for September was the lowest ever recorded; sunshine totals were low, and rainfall over England and Wales was nearly 50 per cent above average. Except for a spell of fairly mild weather at the end of the month, October remained cold; it was sunnier than usual with rainfall amounts about normal. November was another unusually cold month, the coldest since 1925, with considerable snowfall which was particularly heavy in England and Wales during the last four days. Temperature was again well below average in December with widespread snow in the middle of the month; a persistent thick fog affected the London area from the 5th to the 9th.

In England and Wales it was the driest January since 1896; temperatures remained low in the south, but were about normal or slightly above in the north. There was a severe north-westerly gale on the 31st, which caused extensive damage. Although February was mainly dry, considerable snowfall occurred from the 8th to the 14th; after the 17th mild, dry weather prevailed.

The weather for each of the six months September to February (inclusive) is represented graphically on page 104. Figures for six districts of England and Wales are shown in terms of deviation from average for air temperature, sunshine and rainfall. The temperature deviations clearly show the coldness of the autumn weather and the long succession of months with below average temperatures—a reversal of the deviations during the previous summer. The autumn rainfall is about average but the late winter rainfall is deficient; in general, September and January were dull months, but December was sunnier than usual.

# NEW OR UNCOMMON PLANT DISEASES AND PESTS IN ENGLAND AND WALES

***Stagonospora curtisii* on Narcissus Bulbs.** In November 1951, Mr. W. Buddin called my attention to a dark web of sterile mycelium between the scales of a narcissus bulb, and the possibility that it was *Stagonospora curtisii* (Berk.) Sacc. was investigated.The mycelium was isolated in pure culture, and in the spring of 1952 a pure culture of *S. curtisii* was obtained from a single quadricellular pycnidiospore from a narcissus leaf infected with Leaf Scorch. The two cultures were then compared. They showed a very close resemblance in cultural characters, and when inoculated on to autoclaved and fresh narcissus leaves both produced abundant pycnidia with the unicellular pycnidiospores described by Creager (*Phytopathology*, 1933, **23**, 770–86). This record of *S. curtisii* perennating inside narcissus bulbs confirms the observation made by Feekes (*Thesis, Baarn, N.V. Hollandia-Drukkerij*, 1931). E. T. ROBERTS

* These notes, and the diagram on page 104, are provided by the Agricultural Branch of the Meteorological Office, and published by permission of the Director.

**Eelworm in Gypsophila and Aubretia.** In May 1952, the Provincial Advisory Entomologist at Reading was asked to examine plants of *Gypsophila paniculata* L. "Bristol Fairy" propagated by shoot cuttings, from a nursery in Middlesex. The plants were stunted and the leaves twisted (Plate IV), and subsequently it was found that very few flowering stems developed. The plants were infested with *Ditylenchus dipsaci* (Kühn) Filipjev. A general inspection of the nursery showed that many beds of *Phlox paniculata* L. were infested with *D. dipsaci*, as also were some varieties of *Aubretia deltoidea* DC. which showed dwarfing, stunting, and failure to flower. Stocks of *Gypsophila paniculata* on three other nurseries in the area were later found to be infested. Host transference studies were made at Harpenden and Reading. At Harpenden, *D. dipsaci* from infested phlox plants from a local source was transferred to *Gypsophila paniculata* "Compacta" grown from seed. The inoculated seedlings showed swellings of the hypocotyl and distortions of the cotyledons. Staining with Flemming's solution revealed eelworms and eggs in the affected tissue (Inset, Plate IV). Many of the seedlings were killed but some grew into young plants which were stunted and malformed like those from the nursery in Middlesex. Inoculum from the infested seedlings was transferred back to a healthy phlox plant which became infested and developed typical symptoms. *D. dipsaci* was also successfully transferred from infested aubretia from the original nursery to gypsophila grown from seed. At Reading, *D. dipsaci* was successfully transferred from infested gypsophila, phlox and aubretia plants from the same nursery to both gypsophila and phlox from eelworm-free stocks. Both gypsophila and aubretia are new hosts for *D. dipsaci*, and it seems probable that the race of the eelworm infesting them is that common on phlox.

J. W. BRYDEN, D. W. EMPSON AND J. F. SOUTHEY

**Violet Root Rot on Primula.** In October 1952 many plants of *Primula* sp. growing in a nursery at Bricket Wood, Herts, had turned yellow and wilted. The new roots appeared to be healthy, but all the old roots were rotting and many of them were covered with the characteristic *corps miliaires* of *Helicobasidium purpureum* Pat. This fungus does not seem to have previously been recorded on *Primula* species.

J. E. E. JENKINS

**Powdery Scab on Solanum.** Following up the record of *Spongospora subterranea* on tomatoes by Dillon Weston *et al* (*Plant Pathology*, 1952, **1**, 102), experiments on the susceptibility of non-tuber forming *Solanum* spp. were carried out at Cambridge in 1952. Seeds of *S. nigrum*, *S. dulcamara*, *S. douglasii*, *S. rostratum*, *S. mineatum*, *S. nodiflorum*, *S. tomentosum*, *S. pyracanthum*, and of two tomato varieties (Moneymaker and Open Air Wonder), were sown in boxes containing sterilized soil mixed with pieces of potato skin bearing Powdery Scab lesions. Later, seedlings of all the test plants were transplanted to a bed in a glasshouse, and seedlings of all except *S. nigrum* and *S. dulcamara* were put in a plot out of doors. No galls were formed on the roots of any of the plants grown in the glasshouse ; while on the plot outside only the two tomato varieties and *S. mineatum* became infected. The galls on the tomatoes and on *S. mineatum* were restricted mainly to the base of the tap root.

JUNE V. IVES



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